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COMPARATIVE READABILITY OF ENROUTE LOW ALTITUDE CHARTS WITH AND--ETC(U)
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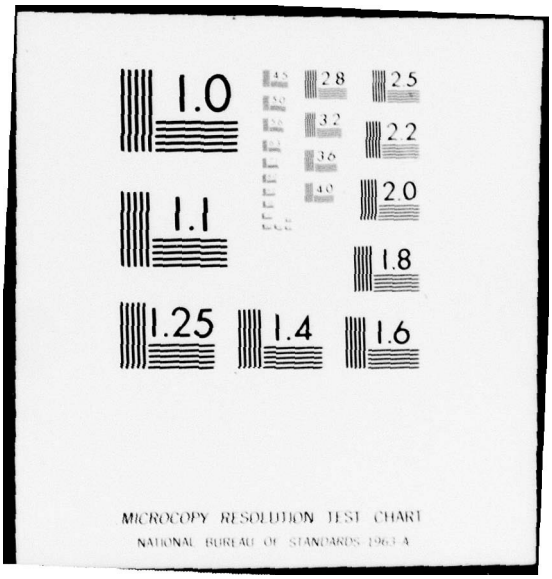
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FAA-AM-78-17

COMPARATIVE READABILITY OF ENROUTE LOW ALTITUDE CHARTS WITH AND WITHOUT TERRAIN DEPICTION

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16. Abstract

The U.S. National Ocean Survey has issued an experimental copy of Enroute Low Altitude Chart L-3/4 dated April 21, 1977, as part of a program to explore the feasibility of introducing terrain depiction on the charts. The FAA's Air Traffic Service (AAT-1) requested the Office of Aviation Medicine to determine what derogatory effects such a change might have on the usability of the charts.

It was found in the study that shaded terrain depiction reduces readability of alphanumeric data as measured by increases in reading errors and reading time. Losses are attributed to the low figure-to-ground contrast ratios between the chart legends and the terrain background. Losses are most pronounced for alphanumeric data printed in small character sizes and with light inking densities. Losses are also evident for some large character sizes and heavy inking densities where mountainous terrain is depicted by heavy inking densities. Losses are particularly evident under low luminance levels but also occur to a lesser extent at elevated luminance levels. Differences between the experimental and standard versions of the charts are least pronounced when the terrain depiction introduced only a moderate reduction in figure-to-ground contrast level and the items were viewed at elevated luminance levels.

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COMPARATIVE READABILITY OF ENROUTE LOW ALTITUDE CHARTS WITH AND WITHOUT TERRAIN DEPICTION

I. Introduction.

The U.S. National Ocean Survey has issued an experimental copy of Enroute Low Altitude Chart L-3/4 dated April 21, 1977, that depicts terrain features in shaded relief and, additionally, provides Maximum Elevation Figures (MEF). In addition to soliciting user comments, the FAA Air Traffic Service (AAT-1) requested the Office of Aviation Medicine to conduct a study to determine how introduction of terrain depiction might affect usability of the charts.

The most obvious effect of shaded relief terrain depiction might be to impair readability of alphanumeric data on the charts. Where mountainous terrain is depicted as background to such data, the contrast ratio is considerably reduced from ratios found on standard charts.

A limited study of the comparative readability of selected categories of data appearing on the charts was conducted by the Vision Research Unit of the FAA Civil Aeromedical Institute's Aviation Physiology Laboratory (AAC-115). The study was restricted to consideration of simple readability as a discrimination task and did not address such factors as search time for specific information or the ability to use the charts in flight.

II. Methods.

Five categories of information appearing on the experimental terrain depiction versions of Enroute Low Altitude Charts L-3 and L-4 were selected as being representative of the alphanumeric content of the charts. The five categories are as follows: (i) UHF/VHF Airway and Route Data, (ii) Aerodromes Without Published Instrument Approach Procedures, (iii) Air/Ground Communication Boxes, (iv) ARTCC Remoted Site Boxes, and (v) Maximum Elevation Figures.

Six samples of each of the first four categories were selected from the experimental charts. Three samples in each category were chosen as representative of a dense terrain background (low terrain contrast) and three as representative of an intermediate terrain background (moderate terrain contrast). In addition, 12 MEF figures

were selected from the terrain depiction chart to provide four samples at each of three relative contrast ratios (high, medium, and low). No attempt was made to quantify the contrast ratios or equate them within categories on other than a subjective basis. A listing of the test items (samples) is given in Table 1.

The selected test items were cut from the experimental versions of the charts in rectangular sections. Corresponding samples, except for MEF numerals, were cut from standard issues of the charts. Extraneous data appearing on the 60 test items were deleted to minimize confusion with the data to be evaluated. The items were then mounted in four random sequences on a display drum. Items were presented singly through a 2.4- by 3.0-cm (0.9- by 1.2-in) viewing aperture in a neutral-gray occluder plate.

The viewing aperture and the surrounding area were illuminated by a 60-W incandescent bulb (General Electric Daylight Blue) mounted in a stainless steel reflector. Luminance levels of 0.25, 1.00, and 4.00 fL were achieved by regulating the voltage applied to the bulb. Luminance in the aperture was measured by a Pritchard Spectra Photometer from a white oxide diffuser plaque immediately behind the aperture.

Test subjects were 11 male and 7 female non-pilot volunteers. Non-pilot subjects were used in order to avoid the confounding factor of variable experience levels found in the pilot population. All subjects had 20/20 near visual acuity corrected by reading glasses or bifocal lenses when necessary. Subjects' ages ranged from 27 to 58 years with a mean age of 45 years. The subjects viewed the display from a distance of 40 cm (15.7 in) as measured from the apex of the cornea to the center of the aperture.

The subjects were read the instructions and shown a representative sample of each category of test items. It was emphasized that they should respond as quickly as was consistent with accuracy and completeness and should not spend undue time on difficult items. The display illumination was adjusted to the level specified for the first trial and the room lights were extinguished. A 2-minute adaptation period preceded the beginning of the first series of test items. The 60 items were presented with a short interruption after every 15th presentation to reposition the drum for the next list. When subjects had completed the last item, the illumination was adjusted to the next level and the procedure repeated. A third trial

TABLE 1. Test Items With Chart Locations

TEST ITEM	CHART REFERENCE	
UHF/VHF Airway and Route Data		
Moderate Terrain Contrast		
V-280	105°00' W	33°00' N
V-25	120°00' W	34°40' N
V-197	118°30' W	35°00' N
Low Terrain Contrast		
V-105-257	112°15' W	34°15' N
V-190	110°15' W	34°00' N
V-237	114°30' W	35°10' N
Aerodome Legends		
Moderate Terrain Contrast		
Conchas State Park	104°15' W	35°20' N
Grants-Milan	108°00' W	35°15' N
Diamond A. Ranch	105°10' W	33°20' N
Low Terrain Contrast		
Transwestern	109°15' W	35°30' N
St. Johns	109°30' W	34°30' N
Bagdad	113°10' W	34°40' N
Air/Ground Communication		
Moderate Terrain Contrast		
Thermal	116°25' W	33°35' N
Santa Barbara	119°35' W	34°35' N
San Luis Obispo	120°30' W	35°15' N
Low Terrain Contrast		
St. Johns	109°20' W	34°15' N
Santa Fe	106°30' W	35°45' N
Zuni	109°15' W	35°20' N

TABLE 1. Test Items With Chart Locations (Cont.)

TEST ITEM	CHART REFERENCE	
ARTCC Remoted Sites		
Moderate Terrain Contrast		
Albuquerque - Tucumcari	103°45' W	35°25' N
Los Angeles - Julian	116°25' W	33°00' N
Albuquerque - Clines Cr.	105°25' W	35°10' N
Low Terrain Contrast		
Albuquerque - Globe	111°00' W	33°05' N
Los Angeles - Seligman	113°00' W	35°20' N
Albuquerque - Truth or Consequences	107°50' W	33°05' N
Maximum Elevation Figures		
High Terrain Contrast		
6 - 2	104-105° W	34-35° N
10 - 4	117-118° W	34-35° N
4 - 8	102-103° W	35-36° N
5 - 7	103-104° W	34-35° N
Moderate Terrain Contrast		
9 - 1	104-105° W	31-32° N
10 - 0	105-106° W	32-33° N
11 - 2	116-117° W	33-34° N
6 - 9	116-117° W	32-33° N
Low Terrain Contrast		
9 - 5	110-111° W	32-33° N
11 - 8	109-110° W	33-34° N
11 - 1	109-110° W	32-33° N
7 - 7	110-111° W	35-36° N

was then run with the last illumination level for a total of three presentations of the 60 items. Illumination levels and list sequences were counterbalanced to minimize systematic bias.

Subjects responded by reading aloud all the alphanumeric data appearing in each test item. Responses were tape-recorded for subsequent scoring of error content and response time.

III. Results.

The results for the four categories of information appearing on both versions of the chart are presented in Tables 2-5. The introduction of terrain depiction resulted in a variable degree of loss of readability of alphanumeric data as demonstrated by increased frequency of errors and increased reading times. The loss of readability was minimal where: (i) the terrain depiction introduced only a moderate reduction in figure-to-ground contrast levels, (ii) character sizes were relatively large and/or printed with a heavy inking density, and (iii) the illumination was at least 1.00 fL.

Three types of reading errors are identified in the tables. "Misreading" errors are those in which the test item was read correctly except for one or more digits in a large group. "Major Omission" errors are those in which a complete line, including a place name or digit group, were omitted. "No Response" errors are those for which the subjects reported inability to read any part of the test item. The "Error Rate" expresses the total number of errors as a percent of the total number of responses. Percent values have been rounded to the nearest full percentage point.

In addition, two types of "Time Scores" are presented in the tables. "Recognition Time" is the time lapse between the presentation of the test item and the initiation of the verbal response. If subjects reported inability to read the item, recognition time values were scored as 15 seconds to provide a numerical value for statistical computation. "Reading Time" is the time lapse between presentation of the test item and the completion of the verbal response. If subjects reported inability to read the item, reading time values were scored as 30 seconds. Scores of 15 and 30 seconds noted above were selected to represent "Recognition Time" and "Reading Times"

TABLE 2. Comparative Error and Time Score for UHF/VHF Airway and Route Data at Two Contrast Levels and Three Luminance Levels

			0.25 fL		1.00 fL		4.00 fL	
			Original	Terrain	Original	Terrain	Original	Terrain
MODERATE CONTRAST	ERROR SCORE	Misreading	2	6	0	1	0	0
		Major Omission	0	0	0	0	0	0
		No Response	0	0	0	0	0	0
		Total Errors	2	6	0	1	0	0
		Error Rate (%)	4	11	0	2	0	0
	TIME SCORE	Recognition Time (sec)	1.66	1.94	1.29	1.31	1.14	1.18
		Percent Increase	--	17	--	2	--	4
		Reading Time (sec)	6.01	7.38	5.23	5.13	5.23	5.20
		Percent Increase	--	23	--	(2)	--	(1)
LOW CONTRAST	ERROR SCORE	Misreading	0	19	0	11	0	9
		Major Omission	0	6	0	0	0	0
		No Response	0	2	0	0	0	0
		Total Errors	0	27	0	11	0	9
		Error Rate (%)	0	50	0	20	0	17
	TIME SCORE	Recognition Time (sec)	1.59	3.36	1.26	1.71	1.26	1.34
		Percent Increase	--	111	--	36	--	6
		Reading Time (sec)	7.67	13.76	6.79	8.40	6.87	7.44
		Percent Increase	--	79	--	24	--	8

TABLE 3. Comparative Error and Time Score for Aerodromes Without Published Instrument Approach Procedures at Two Contrast Levels and Three Luminance Levels

			0.25 fL		1.00 fL		4.00 fL	
			Original	Terrain	Original	Terrain	Original	Terrain
MODERATE CONTRAST	ERROR SCORE	Misreading	2	4	0	1	1	0
		Major Omission	0	3	0	0	0	0
		No Response	0	0	0	0	0	0
		Total Errors	2	7	0	1	1	0
		Error Rate (%)	4	13	0	2	2	0
	TIME SCORE	Recognition Time (sec)	1.95	2.60	1.45	1.58	1.20	1.34
		Percent Increase	--	33	--	9	--	12
		Reading Time(sec)	7.44	9.82	5.63	6.34	5.34	5.85
		Percent Increase	--	32	--	13	--	10
LOW CONTRAST	ERROR SCORE	Misreading	5	15	0	12	0	13
		Major Omission	1	7	0	7	0	1
		No Response	0	20	0	3	0	0
		Total Errors	6	42	0	22	0	14
		Error Rate (%)	11	78	0	41	0	26
	TIME SCORE	Recognition Time (sec)	2.00	8.35	1.37	4.39	1.06	2.50
		Percent Increase	--	318	--	220	--	136
		Reading Time (sec)	7.90	20.30	6.01	13.10	5.37	9.01
		Percent Increase	--	157	--	118	--	68

TABLE 4. Comparative Error and Time Score for Air/Ground Communication Boxes at Two Contrast Levels and Three Luminance Levels

			0.25 fL		1.00 fL		4.00 fL	
			Original	Terrain	Original	Terrain	Original	Terrain
MODERATE CONTRAST	ERROR SCORE	Misreading	1	5	0	0	0	0
		Major Omission	0	0	0	0	0	0
		No Response	0	0	0	0	0	0
		Total Errors	1	5	0	0	0	0
		Error Rate (%)	2	9	0	0	0	0
	TIME SCORE	Recognition Time (sec)	1.29	1.33	1.02	1.18	1.02	1.11
		Percent Increase	--	3	--	16	--	9
		Reading Time (sec)	7.02	7.82	5.96	6.28	6.00	6.10
		Percent Increase	--	11	--	5	--	2
LOW CONTRAST	ERROR SCORE	Misreading	2	3	0	4	0	0
		Major Omission	1	5	0	0	0	0
		No Response	0	0	0	0	0	0
		Total Errors	3	8	0	4	0	0
		Error Rate (%)	6	15	0	7	0	0
	TIME SCORE	Recognition Time (sec)	1.20	1.76	0.96	1.21	0.94	1.02
		Percent Increase	--	47	--	26	--	9
		Reading Time (sec)	6.70	9.97	5.69	6.51	5.70	5.86
		Percent Increase	--	49	--	14	--	3

TABLE 5. Comparative Error and Time Score for ARTCC Remoted Site Boxes at Two Contrast Levels and Three Luminance Levels

			0.25 fL		1.00 fL		4.00 fL	
			Original	Terrain	Original	Terrain	Original	Terrain
MODERATE CONTRAST	ERROR SCORE	Misreading	9	17	0	7	1	2
		Major Omission	5	15	0	4	0	0
		No Response	0	6	0	0	0	0
		Total Errors	14	38	0	11	1	2
		Error Rate (%)	26	70	0	20	2	4
	TIME SCORE	Recognition Time (sec)	1.53	3.55	1.05	1.68	0.99	1.28
		Percent Increase	--	132	--	60	--	29
		Reading Time (sec)	10.47	15.16	6.21	9.20	5.92	6.59
		Percent Increase	--	45	--	48	--	11
LOW CONTRAST	ERROR SCORE	Misreading	10	8	0	12	0	16
		Major Omission	11	13	0	10	0	8
		No Response	1	31	0	12	0	2
		Total Errors	22	52	0	34	0	26
		Error Rate (%)	41	96	0	63	0	48
	TIME SCORE	Recognition Time (sec)	2.19	10.17	1.17	5.26	0.98	2.23
		Percent Increase	--	364	--	350	--	128
		Reading Time (sec)	13.26	24.87	7.16	17.17	6.18	11.47
		Percent Increase	--	88	--	140	--	86

slightly longer than times required by the slowest reader. If a "Major Omission" error was scored for the item, the actual reading time was doubled, subject to the 30-second maximum value. "Percent Increase" values are the increases in time required to respond to the terrain concept items compared to the standard version of the same items. The two values in parentheses in Table 2 indicate decreases in reading times. All percentage values have been rounded to the nearest full percentage point.

The data for the MEFs are presented in Table 6. The error definitions are the same as for the other categories of information except that the "Major Omission" category is not included because of the limited numeric content of these test items. Time scores for the MEFs follow the criteria for the other categories of test items except that "Recognition Time" was limited to a maximum of 10 seconds and "Reading Time" to a maximum of 20 seconds in order to avoid excessive distortion of time scores for items that normally have a very short reading time. Percent increase values for the medium and low contrast items are based on comparison with the high contrast level items.

IV. Discussion.

An effective terrain depiction format appears to depend on establishment of acceptable contrast ratios between the alphanumeric information and the terrain background. Such ratios must not only provide for adequate readability of the alphanumeric information, but also must accommodate a wide enough range in terrain printing densities to effectively depict the terrain background.

If terrain densities are equal to or less than the intermediate values used in this study, only minimal changes in character size or density will be necessary to assure adequate readability of the charts. If terrain printing densities causing low contrast are utilized, it will be necessary to consider increasing the size of the alphanumeric characters. Contrast enhancement by use of selected color combinations, alternate symbology, and reduction of terrain printing densities behind alphanumeric data (blocking) might also be considered.

Specific recommendations for providing maximum readability of a given format must be developed on the basis of the criteria governing the purpose of the chart. There is abundant

literature addressed to the general problem of readability of the printed word and graphic material. A good summary of map and chart design for aviation has been issued by the Australian Department of Civil Aviation that also includes an extensive reference section providing coverage of the pertinent literature (1).

All subjects in this study had good vision and were viewing the chart elements under ideal laboratory conditions. Common in-flight factors such as degraded visual acuity, vibration, turbulence, distraction and stress would logically be expected to reduce chart readability below the levels found in this study.

TABLE 6. Error and Time Score for Maximum Elevation Figures (MEF) at Three Contrast Levels and Three Luminance Levels

		0.25 fl			1.00 fL			4.00 fL		
		High	Medium	Low	High	Medium	Low	High	Medium	Low
ERROR SCORE	Misreading	0	3	9	0	2	14	0	0	13
	No Response	0	0	26	0	0	16	0	0	6
	Total Errors	0	3	35	0	2	30	0	0	19
	Error Rate (%)	0	4	49	0	3	42	0	0	26
TIME SCORE	Recognition Time (sec)	0.99	1.28	5.42	0.94	1.05	4.23	0.94	1.06	2.78
	Percent Increase	--	29	447	--	12	350	--	13	196
	Reading Time (sec)	1.56	2.03	10.18	1.50	1.65	7.49	1.48	1.67	4.74
	Percent Increase	--	30	553	--	10	399	--	13	220

REFERENCE

1. Watkins, R. D.: The Presentation of Printed Information to Aircraft Pilots, Aviation Medical Branch, Department of Civil Aviation, Aviation Medicine Memorandum No. 27, Melbourne, Australia, 1970.